Design of Buried Thermoplastics Pipes

Results of a European research project
by APME & TEPPFA
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Organisations supporting the project

- **TEPPFA**
  The European Plastics Pipe and Fitting Association

- **APME**
  Association of Plastics Manufacturers in Europe
Current situation

- Rigid materials still dominate on many European markets.
- Prevailing design practices often tailored for rigid pipes.
- Flexibility considered as a weakness.
- Designers not always familiar with the behavior of plastic pipes when buried underground.

Share of Plastic Pipes in Municipal Sewer Pipelines

- Scandinavia
- France
- Austria
- Germany
- UK

0 50 100

Plastics Other
Misconceptions about plastics pipes

- Deflection increases with installation depth and with traffic load.
- Pipe ring stiffness is the governing factor determining the performance.
- Pipe loses stiffness with time, the load bearing capacity reduces.
- To predict the structural performance an extensive design method is needed.
- Flexible behaviour is a disadvantage.
- Deflected pipe loses its discharge capacity and tightness.

⇒ TEPPFA and APME started an extensive research project to address these arguments.
Try doing this with plastics

Source:
American Concrete Association

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Objectives of the project

- Show the relative importance of the parameters.
- Prove flexibility to be a strength instead of a disadvantage.
- Develop a design approach in balance with achievable installation quality and actual behaviour.
- Contribute to the development of the European standards with real field trials / test results.
- Provide material to communicate the project results to the marketplace.
Project Group

- Frans Alferink, Wavin M&T, Project manager (NL)
- Lars-Eric Janson, SWECO, Supervisor (S)
- Jonathan Olliff, Montgomery / Watson, Supervisor (UK)
## Steering Committee

<table>
<thead>
<tr>
<th>Name</th>
<th>Company / Association</th>
<th>Country</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingemar Björklund</td>
<td>KWH Pipe / NPG</td>
<td>(S)</td>
<td>Chairman</td>
</tr>
<tr>
<td>Helmut Leitner</td>
<td>Solvay / APME</td>
<td>(B)</td>
<td></td>
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<tr>
<td>Tiem Meijering</td>
<td>Polva-Pipelife / FKS (NL)</td>
<td></td>
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<tr>
<td>Michael Giay</td>
<td>REHAU / ON</td>
<td>(A)</td>
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<tr>
<td>Dieter Scharwächter</td>
<td>Uponor / KRV</td>
<td>(D)</td>
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<tr>
<td>Jacques Nury</td>
<td>Alphacan / STRPE-PVC</td>
<td>(F)</td>
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<tr>
<td>Constantino Gonzalez</td>
<td>ITEPE / ASETUB</td>
<td>(E)</td>
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<tr>
<td>Alan Headford</td>
<td>Durapipe-S&amp;LP / BPF</td>
<td>(UK)</td>
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<tr>
<td>Jukka Kallioinen</td>
<td>Uponor</td>
<td>(D)</td>
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<td>Loek Wubbolt</td>
<td>Omniplast</td>
<td>(NL)</td>
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<td>Trefor Jones</td>
<td>Wavin</td>
<td>(UK)</td>
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<tr>
<td>Frans Alferink</td>
<td>Wavin M&amp;T</td>
<td>(NL)</td>
<td>Secretary</td>
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Project set-up

Started in July 1996, Costs : Euro 450.000,=

- Full scale field trials with different materials, stiffnesses, soils and installation conditions carried out in Haarle and Wons (NL), involving:
  - Traffic load simulations
  - Depth variations
  - Internal pressure
  - Time effect
  - Supporting laboratory tests.
- Design exercises together with leading European experts to compare existing calculation methods with results from field measurements.
- Evaluation with European design experts in a workshop.
## European experts involved

<table>
<thead>
<tr>
<th>Expert</th>
<th>Design Method</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Günther Leonhardt</td>
<td>EN 1295</td>
<td>(Germany)</td>
</tr>
<tr>
<td>Marcel Gerbault</td>
<td>ATV A 127</td>
<td>(France)</td>
</tr>
<tr>
<td>Walther Netzer</td>
<td>ÖNORM B 5012</td>
<td>(Austria)</td>
</tr>
<tr>
<td>Lars-Eric Janson</td>
<td>VAV P70</td>
<td>(Sweden)</td>
</tr>
<tr>
<td>Jonathan Olliff</td>
<td>PSSM</td>
<td>(United Kingdom)</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hubert Schneider</td>
<td>GRP-draft</td>
<td>(Germany)</td>
</tr>
<tr>
<td>Frans Alferink</td>
<td>CalVis</td>
<td>(The Netherlands)</td>
</tr>
<tr>
<td>Tiem Meijering</td>
<td>Bossen</td>
<td>(The Netherlands)</td>
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</table>
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### Approach with European design experts

<table>
<thead>
<tr>
<th>Step</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Consultation with experts regarding field trials.</td>
</tr>
<tr>
<td>2</td>
<td>European experts calculating the pipe deflections by using the different methods.</td>
</tr>
<tr>
<td>3</td>
<td>Establishing test fields and carrying out extensive measurements.</td>
</tr>
<tr>
<td>4</td>
<td>Continuing the field measurements at defined times.</td>
</tr>
<tr>
<td>5</td>
<td>Evaluation of all results in a two day workshop (December 1997).</td>
</tr>
</tbody>
</table>
## The field trials: Installed pipes

<table>
<thead>
<tr>
<th>Material</th>
<th>Stiffness</th>
<th>Cover</th>
<th>Installed length</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Silty sand</strong>, November 1996</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVC</td>
<td>2 and 4</td>
<td>1.15</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.85</td>
<td>60</td>
</tr>
<tr>
<td>PE</td>
<td>5</td>
<td>1.15</td>
<td>45</td>
</tr>
<tr>
<td>Steel</td>
<td>4</td>
<td>1.85</td>
<td>20</td>
</tr>
<tr>
<td><strong>Silty clay</strong>, August 1997</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PE</td>
<td>5</td>
<td>1.15</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.0</td>
<td>60</td>
</tr>
</tbody>
</table>
Documented test data

**Soil**
- Grain size distribution
- Grain shape
- Proctor density
- Menard test
- Cone penetration test
- Tri-axial test (clay)
- Cone-pressiometer test
- Impact cone test
- Oedometer test

**Pipe**
- Dimensions
- Stiffness
- Creep ratio
- Deflections
  - time dependency
  - under internal pressure
  - under traffic load
  - under ground water
- Strain under deformation
Natural variations in soil

Grain size distributions of sand taken at two different depths
Installation practices used in the project

Well

Moderate

None
Imagine the potential

Moderate

None

Well

Installation (Compaction)

Granular

Cohesive

Embedment Soil

Sand trials, in silty sand

Trials in weak clay

Position of trials

Position of trials in generalised application window

recommended

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Pipe deflection

Measured deflections for different types of installation

<table>
<thead>
<tr>
<th>Distance [m]</th>
<th>Vertical deflection [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>1 -2 -2 0 2 4 6 0 4 6 8</td>
</tr>
<tr>
<td>40</td>
<td>1 -2 -2 0 2 4 6 0 4 6 8</td>
</tr>
</tbody>
</table>

Well

Moderate

None
Findings from workshop discussions

- "Installation of pipeline systems varies from meter to meter depending on many aspects such as workmanship, native soil variations, weather conditions and logistics in the field."

- “Consequently, the installation variability results in variations in ring deflection along the pipeline for flexible pipes and in variations in bending moments along the pipeline for rigid and semi-rigid pipes."
No difference between PVC / Steel

Time dependency of the deflection

Measured

PVC

Steel
Calculated and measured deflections

Granular soil, good installation

Deflection [%]

Methods
A B C D E F G H I

measured
Imagine the potential

Calculated and measured deflections

Granular soil, poor installation

Methods
A B C D E F G H I

Deflection [%]
0 2 4 6 8 10

measured
Calculated and measured deflections

Granular soil, poor installation with and without traffic load

Effect of traffic

Deflection Increase [%]

Methods

A B C E F G H Measure

Measured
Summary of the main results

- Good understanding of soil-pipe interaction.
- 20 well documented data sets on the different installations.
- Simplified approach with a new design-tool applicable to the majority of pipe installations.
- More confidence in plastics pipe performance even under poor installation conditions.
The pipe soil interaction

Ring deflection of flexible pipes is controlled by the settlement of the soil. After settlement, traffic and other loads do not affect pipe deflection. Deflection is safety!

When pipes are relatively more rigid than the soil, the traffic and other loads have to be resisted by the pipe.
Facts about deflection

- Depth of cover is not relevant.
- Traffic load has no significant effect.
- Deflection and its variation depends more on the installation quality than on the pipe stiffness.
Facts about deflection

- Installation phase
- Settlement phase

Deflection [%]

Traffic effect

Time [years]

0  100

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Imagine the potential
Facts about deflection

- Recommended max. values:
  8% initial, 12.5% final.
  (ISO TR 7073)

- Pipes deflected up to 10% - only 2.5% reduction in discharge capacity.

Deflection is NO issue!

Discharge capacity as a function of pipe deflection

Discharge capacity [%]

Pipe deflection [%]
Pipe deflection after installation

The average deflections immediately after installation are represented by the lower boundary of each area, and the maximum values by the upper boundaries.
Imagine the potential

\[(\delta/d)_{\text{final}} = (\delta/d)_{\text{inst.}} + C_f\]
Imagine the potential

Installation practices used in the project

- \( C_f = 1.0 \) (Well)
- \( C_f = 2.0 \) (Moderate)
- \( C_f \) granular = 3.0
  \( C_f \) cohesive = 4.0 (None)
The paradox

“Sophisticated design methods rely on the quality of the input parameters and that the installation is strict according to the prescriptions.

In such cases a “Well” type of installation is obtained, resulting in very low deflections, and hence design is not important in such cases.

When the quality of the input values is less good, as when installations are becoming more difficult and hence limit state conditions are more likely to occur, sophisticated design methods are no longer appropriate”.

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Imagine the potential effect of parameters on deflection.

- **Installation Depth**: Most important parameter.
- **Pipe stiffness**: Increased depth leads to decreased deflection.

Relative contribution [%] vs parameter:

- Installation
- Depth
- Pipe stiffness
- Pipe Material
Conclusions

- Depth and traffic load have no effect on the final deflection.
- For “Well” to “None” type of installation:
  - pipe stiffness not important
  - creep ratio / material not important
  - deflections stay very low
  - limit state conditions are not likely to occur

Key property : Strainability !

Note: Proven for pipes in the stiffness range 2 to 16 kN/m$^2$. 
Impressions